

**Beach Water Quality
Models: Lessons Learned
about Water Quality
Predictive Models for
Bradford and South Shore
Beaches in Milwaukee**



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Beach Water Quality Monitoring

- Primary purpose is to provide public with advisory about how the water may affect their health and safety
- Traditionally, health and parks departments have monitored *E. coli* (indicator of contamination and pathogens)
- Also can use other variables to “predict” *E. coli* level (Beach Water Quality Models)



Advisories

- Posted on website (Wisconsin Beachhealth)
<http://infotrek.er.usgs.gov/beachhealth>
- Available statewide, phone hotline (800#)
- Signs at beaches
- *Proposed 2004 signs follow*



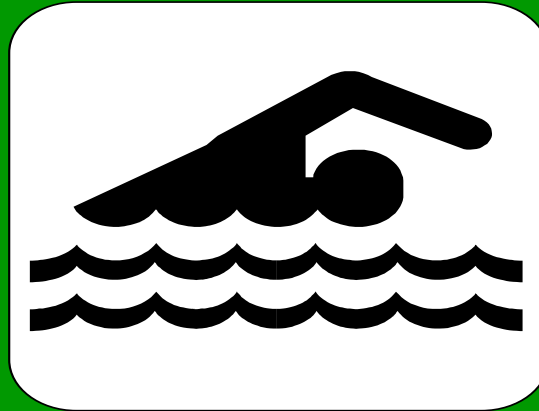
ATTENTION

THIS AREA IS MONITORED REGULARLY FOR *E. COLI* BACTERIA, AN INDICATOR OF THE POSSIBLE PRESENCE OF PATHOGENS THAT CAN CAUSE HUMAN HEALTH RISKS. AS WITH ALL NATURAL BODIES OF WATER, THIS LAKESHORE CONTAINS MICROSCOPIC ORGANISMS. IF BACTERIA COUNTS ARE ABOVE STATE HEALTH STANDARDS, AN ADVISORY OR CLOSURE SIGN WILL BE POSTED AT THIS LOCATION.

SWIM AT YOUR OWN RISK

For latest water conditions: 1- 877 BEACHES ext.1452
www.beachhealth.gov

THIS AREA IS
OPEN
TO SWIMMING



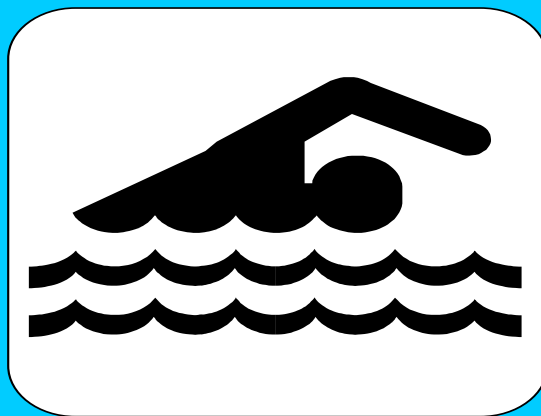
Based on recent monitoring for E. coli bacteria

FOR MORE INFORMATION:

1-800-BEACHES

www.beachhealth.net

WATER QUALITY TODAY IS



GOOD

BASED ON RECENT MONITORING FOR *E. coli* BACTERIA

FOR MORE INFORMATION:

1-800-BEACHES ext. 1452

www.beachhealth.net

WARNING: WATER QUALITY TODAY IS

POOR

Based on recent monitoring for E. coli bacteria

Potential Sources of Pollution

- Surface run-off
- Storm & combined sewers
- Wild animal & pet waste
- Illegal boat discharge
- Wastewater treatment plant overflows



What Can I Do to Reduce Pollution?

- Pick up litter, especially diapers
- Bag pet waste and deposit in waste containers
- Do not feed gulls and waterfowl
- Conserve water
- Avoid using chemical fertilizers

Increased Risk of Illness May Be Present

FOR MORE INFORMATION:

1-800-BEACHES ext. 1452

www.beachhealth.net

STOP CLOSED



*Based on recent monitoring for E. coli bacteria
Serious Risk of illness may be present*

THIS AREA IS CLOSED TO SWIMMING

FOR MORE INFORMATION:

1-800-BEACHES

www.beachhealth.net



Why Use Predictive Models?

- With current technology, test results lag 18-24 hours
- Need to know real-time (TODAY) if water is safe to swim in
- Some models may accurately “predict” what the *E. coli* result will be (18-24 hours later) for water quality real-time

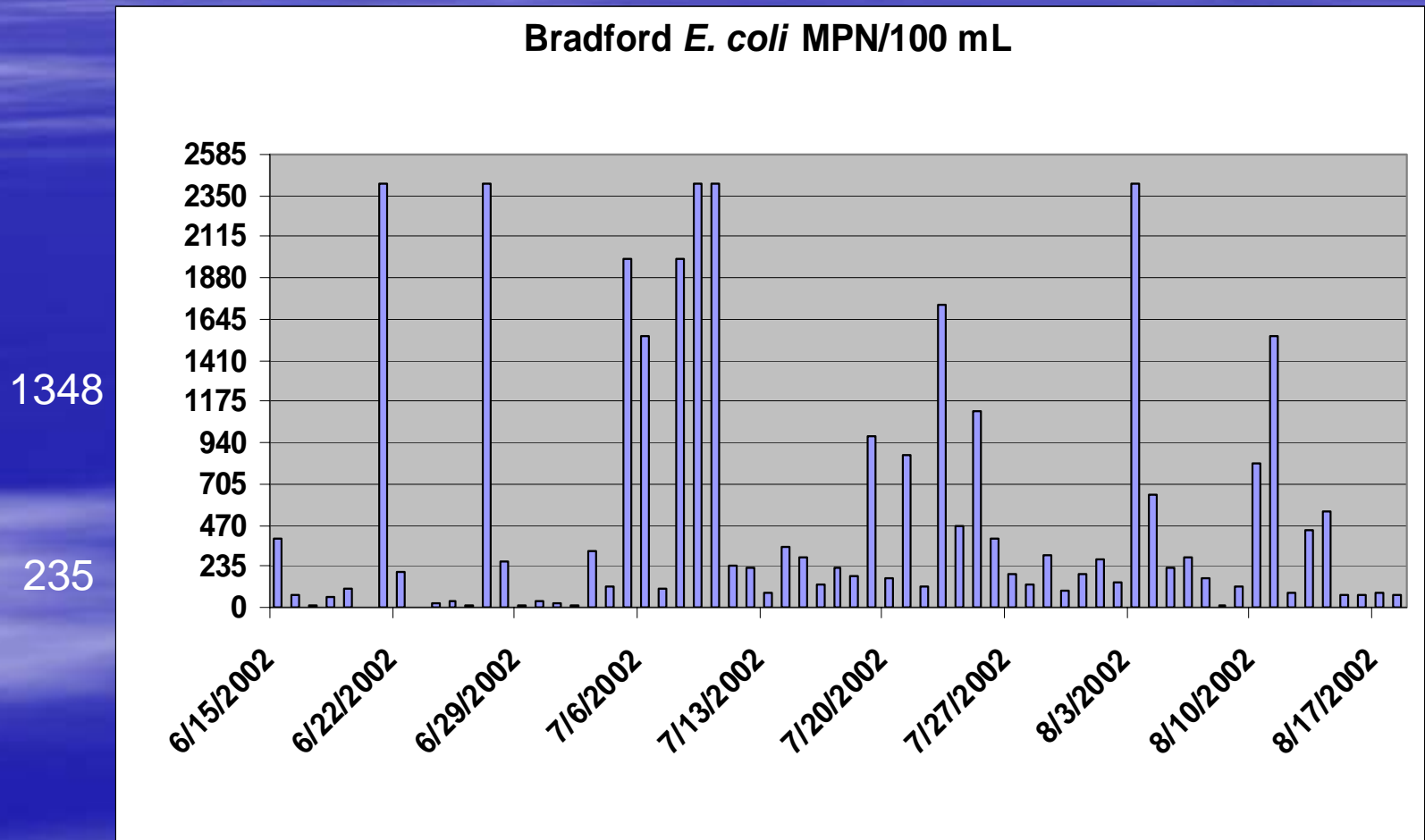


What About Using Yesterday's *E. coli* Level or a Running Geometric Mean???

- Some beaches have water quality that changes significantly from day to day (due to waves, mixing)
- 5 Day Geo Mean expected to be representative of water quality on a given day, wide variation
- Previous day *E. coli* level sometimes used, as representative of or surrogate for current day

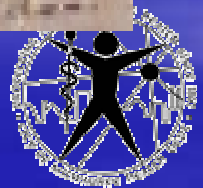


Are Single Samples Predictive of *E. coli* Level the Next Day?



This might work for beaches with

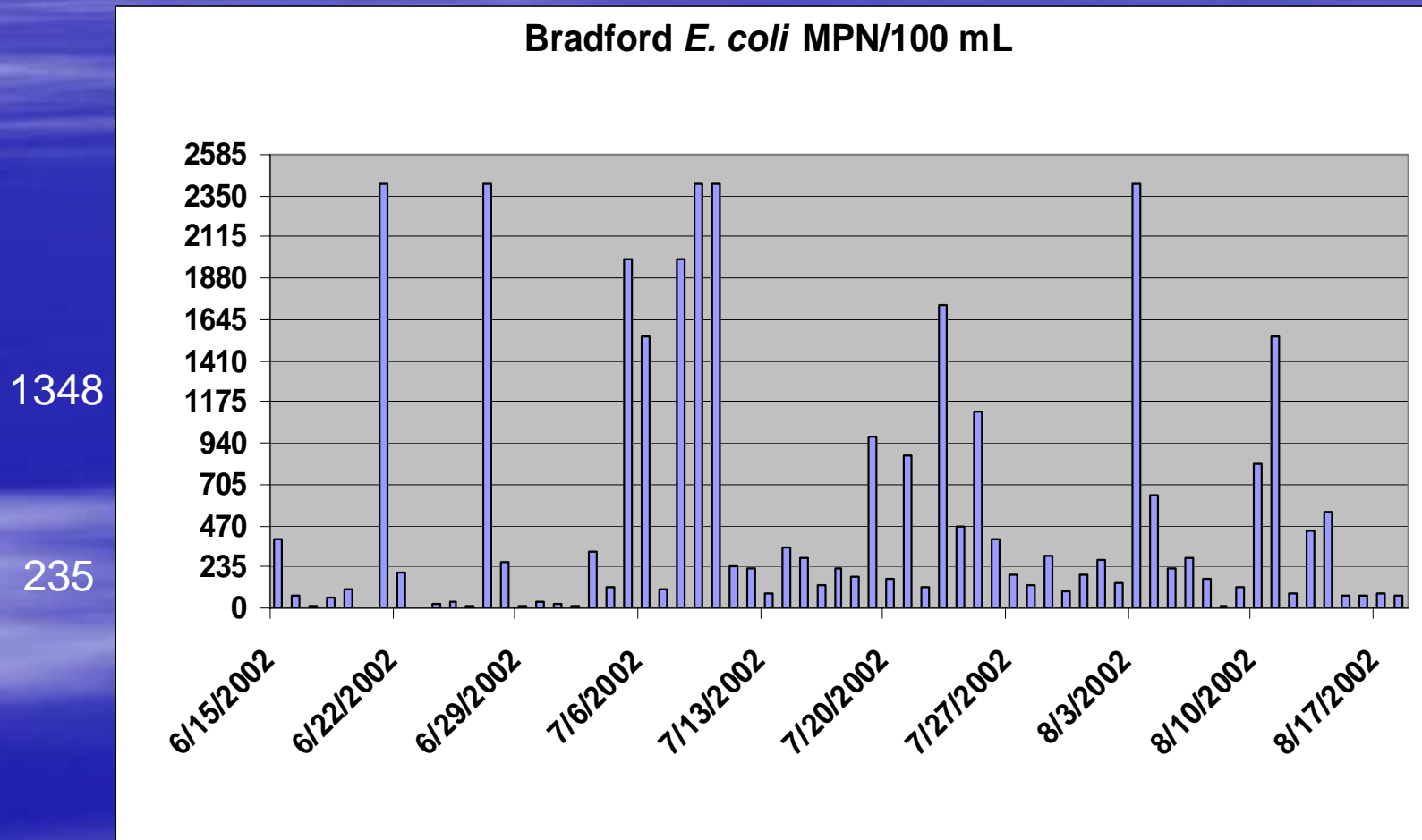
- Low mixing (South Shore, though unpredictable spikes and drops do occur here, elevated levels tend to decrease gradually)



Waves might help with mixing



Are Single Samples Predictive of *E. coli* Level the Next Day?



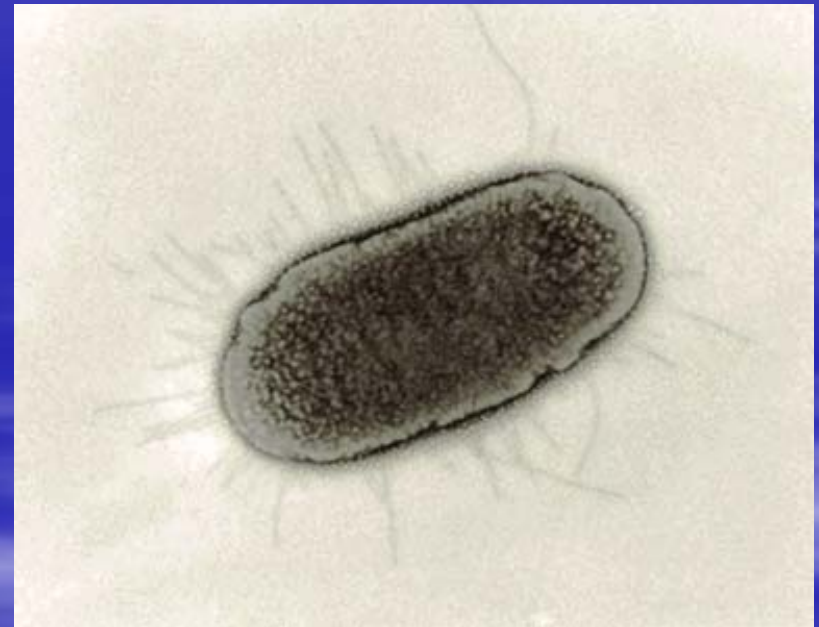
Predictive Models: Background

- In the recent decade public has demanded information (“health risk”)
- Milwaukee effort began in 1980s in partnership with Milwaukee Metropolitan Sewerage District
- Also used in Chicago, other areas
- Early Milwaukee efforts: rainfall as primary predictive variable
- Model correctly about 50% of the time in 1990s
- EPA EMPACT funds: New Models



What are We “Predicting” and What Does it Mean?

- Most models predict *E. coli* level (surrogate)
- Target is >235 or <235 *E. coli* MPN/100 mL or
- >1348 (Bradford) /1872 (South Shore) or <1348 (Bradford) /1872 (South Shore) *E. coli* MPN/100 mL
- *E. coli* is indicator of fecal contamination (warm-blooded animals)
- Appropriateness of indicator depends on contamination sources for beach (*E. coli* subtyping, etc.)



Environmental Variables Used in Models: Bradford

- Traditional: Previous Days *E. coli*, rainfall, CSOs
- Multivariate: used Wind Vector, Water Temp, Algae, CSO Volume, Turbidity
- Adjusted Multivariate: Adjustment factor



Bradford Formula

- $E_c = \exp(0.63 + 0.066W_v + 0.002CSO + 0.032 T_w + 0.37 \text{ algae} + 0.016 T)$
- Wave Vector (Met stn)
- CSO Vol
- Algae 1-3
- Water Temp



Environmental Models, Variables Used McKinley Beach

- Traditional: Previous day's *E.coli*, rainfall, CSOs
- Data was analyzed, but no predictive formula could be calculated



Environmental Variables: South Shore Beach

- Traditional: Rainfall, previous day's *E. coli*, CSOs
- Multivariate: Wind Vector, Water Temp, pH, Conductivity, CSO volume, turbidity, **rainfall**
- Adjusted Multivariate: Adjustment factor



South Shore Formula

- $E_c = \exp(13.0 + 0.37R + 0.054 W_v + 0.038 T_w - 0.006C - 1.1 \text{ pH} + 0.011 \text{ Turbidity} + 0.002 \text{ CSO})$
- Rainfall (Met Stn)
- Wind Vector (Met Stn)
- Water Temp (Sonde)
- Conductivity (Sonde)
- pH (Sonde)
- Turbidity (Sonde)
- CSO Vol



Bradford Beach: What are the potential sources of pollution

- Storm water
- Agricultural/River
- CSOs, diversions (in some recent versions of models, CSOs factor, diversions not yet investigated)
- Domestic and wild animal waste



Bradford Beach: What are the possible sources of *E. coli*?

- Storm water
- Agricultural/River
- CSOs diversions (in some recent versions of models)
- Domestic and wild animal waste
- ***Algae (?)



But What Does the Algae Mean?

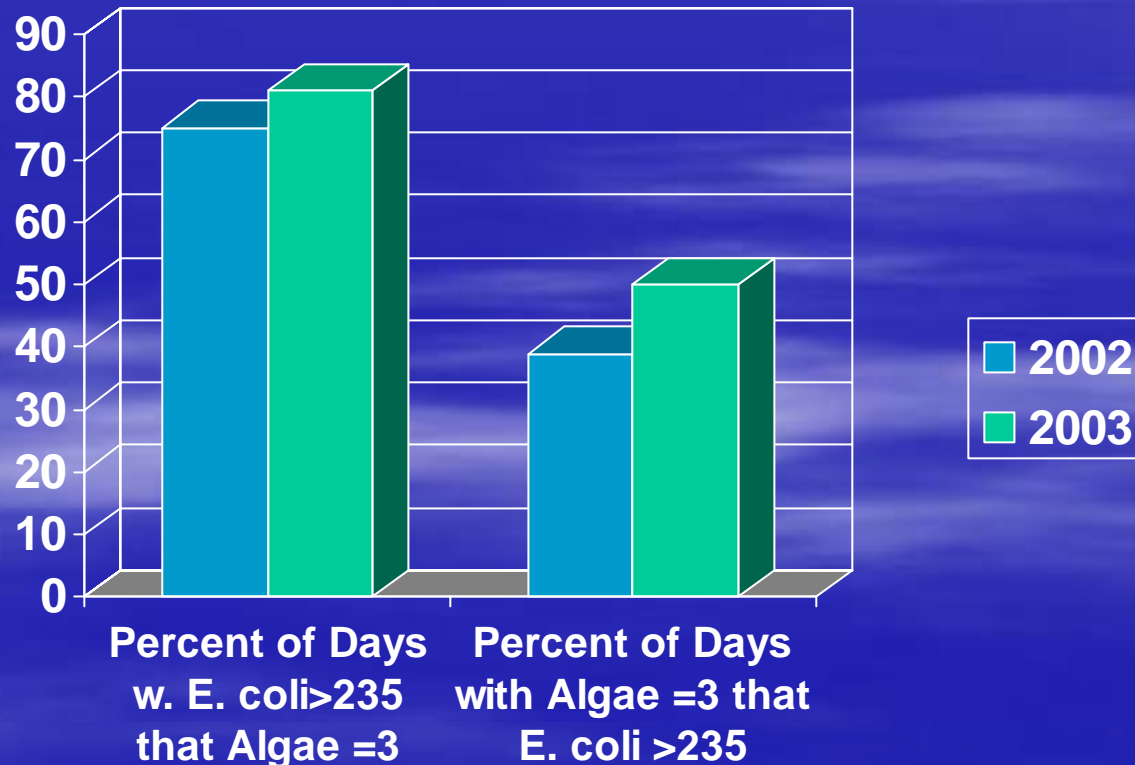
- Nuisance
- Blocks view of bottom
- Odor
- May attract waterfowl/feces, ??pathogens??
- Provides warm, quiet, shallow place for *E. coli* to multiply
- Do the increased *E. coli* numbers mean increased risk???



Algae at Bradford Beach



Presence of Algae and E. coli Levels at Bradford Beach in 2002 and 2003, Memorial Day through Labor Day



More Information Needed About Algae: 2004 “Algae” Form for Bradford

Algae Description

Location: BD N, BD S, MK, SS

Wave action: calm (no movement of water), small waves, medium waves, large waves

****Describe **exactly where the sample is taken from** (within algae, n,s,e,w of algae, from mat or suspended algae)

Do you sink into the “sand” when walking? Where exactly? How extensive?

On land (sand or waterline)

- **Length** of algae per location
- **Width** of algae
- **Age of algae-** How long has it been here-Any additions/subtractions since yesterday?-**Is there an odor?**-What color is it?

In water (beyond solid mat, if solid mat present)

- **Length** of algae per location
- **Width** of algae
- **Age of algae-** How long has it been here-Any additions/subtractions since yesterday?-Is there an odor?-What color is it?



What Works for Bradford Beach: Overall Accuracy??

2002-2003 “Beach” Season

- 5 Day Geo Mean=58-60% Accuracy
- Single Sample=48-60% Accuracy
- Adjusted Multivariate=60% Accuracy
- (Other environmental models about the same or slightly higher, 57-70%)



What Works for Bradford Beach: Predicting Poor Water Quality

***Public Health Goal is to post beaches poor when water is poor (“Sensitivity”)**

2002-2003 “Beach” Season, Sensitivity:

- 5 Day Geomean=14-56%
- Single Sample=32-41%
- **Adjusted Multivariate=79-85%** (Other environmental models=10-38%)
- **Adjusted Multivariate has best sensitivity**

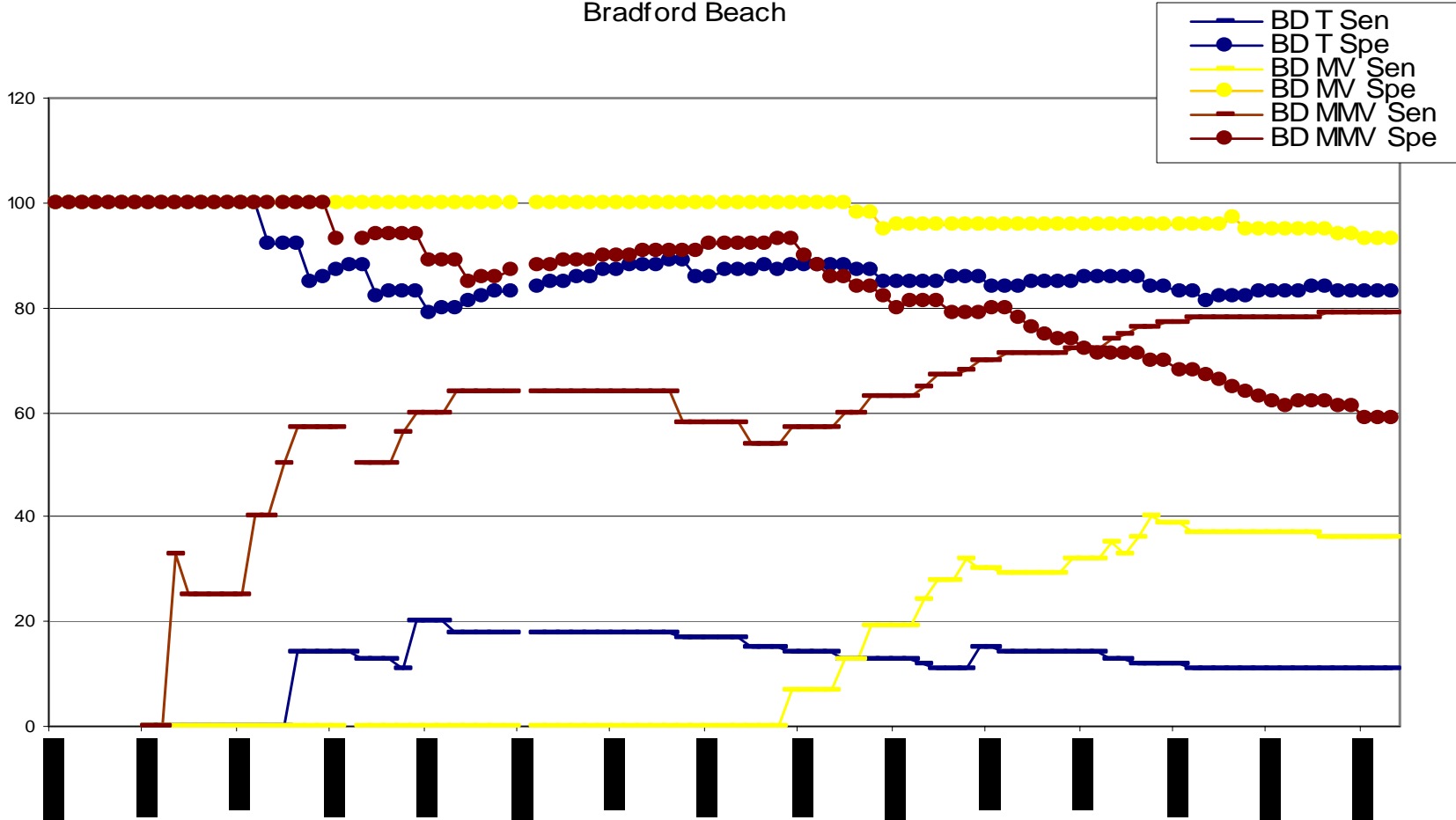


Sensitivity and Specificity Various Models Used for Predicting Water Quality at Milwaukee Beaches 2003

	Traditional n=100		Multivariate		Modified Multivariate	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Bradford	11	83	36 (n=99)	93 (n=99)	79 (n=99)	59 (n=99)
McKinley	8	94	na	na	na	na
South Shore	38	82	10 (n=81)	85 (n=81)	77 (n=81)	28 (n=81)

Bradford

Sensitivity and Specificity of Various Water Quality Predictive models 2003:
Bradford Beach

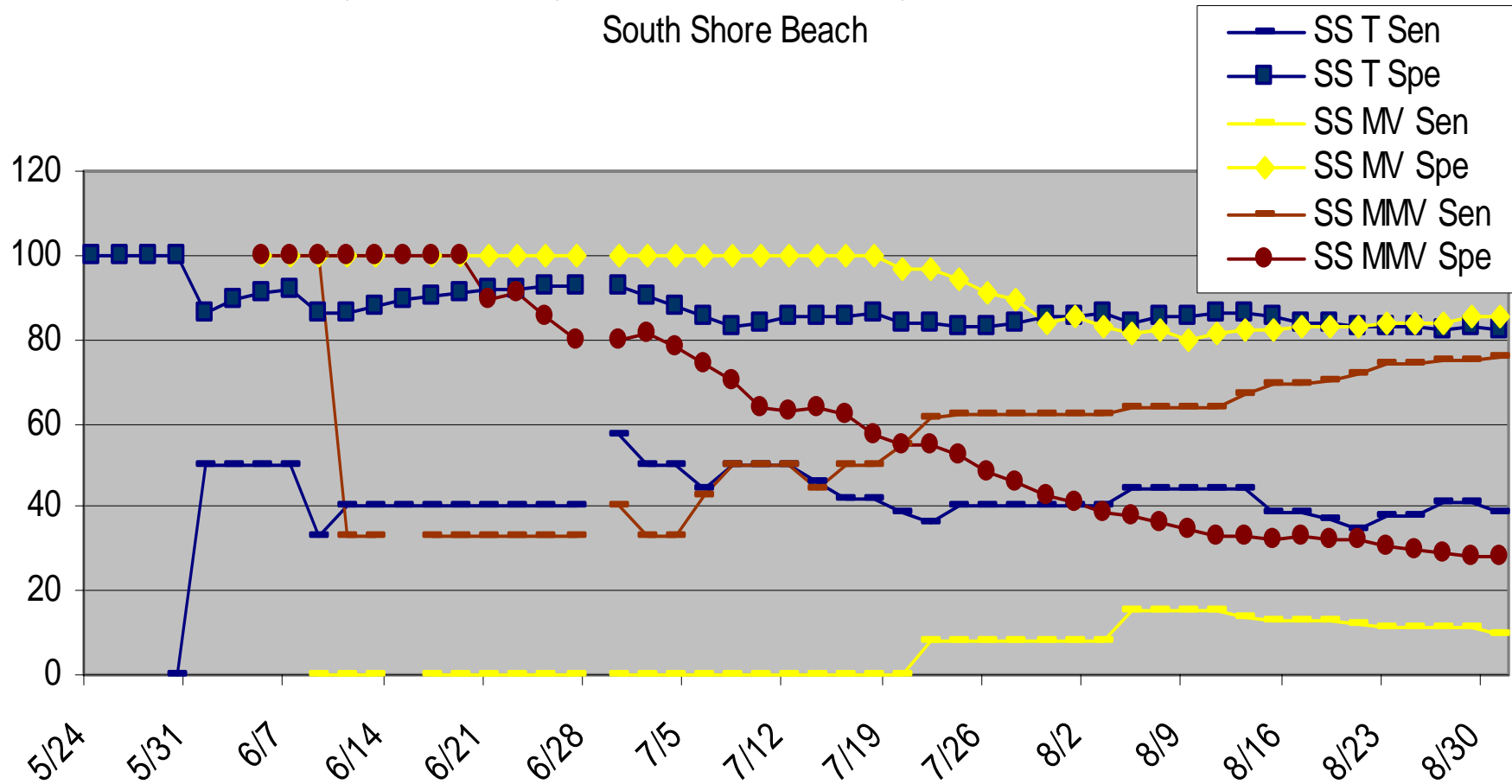


Sensitivity/Specificity Graph: South Shore

Sensitivity and Specificity of Various Water Quality Predictive Models 2003:

South Shore Beach

Sensitivity and Specificity Expressed as %



Bradford Models: A comparison 2002 vs. 2003

	2002		2003	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Traditional (6/15-8/18)	45	78	15	91
Multivariate (6/15-8/18)	43	89	50	95
Multivariate Adjusted (6/15-8/18)	86	57	85	60
Traditional (5/24-9/01)	-	-	11	83
Multivariate (5/24-8/01)	-	-	33	96
Multivariate Adjusted (5/24- 8/01)	-	-	78	68



Variables Measured for Bradford Predictions (Adjusted Multivariate)

- Water temp
- Algae 1-3
- Recent CSO
- Wind Speed and Direction



Improvements Needed in Predictive Models: Bradford Multivariate

- Improvement Most Needed: Specificity
- Sensitivity good, but there are “good” days when beach posted “Poor”
- Need to standardize algae scoring (“Algae Data Sheet”)
- Need to Assure Met Station/transmitted data OK



Improvements Needed: South Shore Model

- Re-fit model with 2003 data (new sonde location)
- Met station maintenance



In Summary (Bradford Beach Water Quality Predictions)

- Sensitivity is a public health goal
- Adjusted Multivariate models may lack specificity, but sensitivity has been good
- Adjusted Multivariate better than other environmental models, previous day's *E. coli* alone, or 5 Day Geo Mean



How Much Does a Model Cost?

- Hardware in Water \$20,000 +/- (4-6 parameters, meteorological station included)
- \$4,000 per year to maintain in-water
- \$15,000 +/- to analyze 1-3 seasons worth of data, 6 +/- parameters
- \$40,000 +/- for 2 years



Alternatives to Automated Monitoring

- Apply for an EPA Grant for “start-up”
- “Borrow” Model from another beach in region - may not be possible currently, but may be possible in the future (Dr. Richard Whitman)
- Try a simpler model (Bradford Model used all manually collected data, except for meteorological=\$15,000??)
- Find other sources of necessary data (WWTPs with Meteorological stations)



What is Needed: Data

- Daily sampling
Sampling after rain or other events
Sampling in dry weather
- More years of data, better
- Met data measured nearby
- Water temp
- Turbidity
- Land use
- Other parameters



A Few Things to Remember

- Whether or not *E. coli* indicates risk depends on source of pollution
- Predicting *E. coli* level may not mean predicting risk unless
- Good info about sources or potential sources
- Need more reliable indicators



Resources

- Richard Whitman, USGS, Models
richard_whitman@usgs.gov (219) 926-8336 (x424)
- Greg Olyphant, Indiana U, Models
olyphant@indiana.edu <http://www.indiana.edu/~geosci/people/faculty/olyphant.html> (812) 855 - 1351
- Mary Ellen Bruesch, Local jurisdiction using In-water monitoring/models, WI
mbrues@milwaukee.gov (414) 286-5744
- Rob Paddock, UW GLWI, In-water monitoring, data transmission to website
rpaddock@uwm.edu (414) 382-1700
- Morgan Schneider, USGS, data transmission to website
mschmidt@usgs.gov (608) 821-3820
- Carolyn McCullough, USGS, data transmission to website
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- Holly Wirick, EPA Region 5, EPA Resources (funding)
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- Judy Beck, EPA Region 5, EPA Resources (funding)
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